An Evaluation of Multilevel Operations For Low-Volume Grocery Items

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PREFACE

This study was conducted under contract by Paul F. Shaffer of the Paul F. Shaffer Co., Miami, Fla. The contract was administered by Jack L. Runyan, marketing specialist, Food Distribution Research Laboratory, Agricultural Marketing Research Institute, Agricultural Research Service.

Special acknowledgment is due to Benner Tea Co., Burlington, Iowa; Florida Affiliated Retail Grocers, Inc., Tampa, Fla.; and Kimbell Grocery Co., Albuquerque, N. Mex., for providing facilities and data for the study.

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An Evaluation of Multilevel Operations For Low-Volume Grocery Items

By Jack L. Runyan and Paul F. Shaffer[1]

SUMMARY

The results of this evaluation showed that multilevel operations will reduce warehouse costs by as much as $17.33 per 1,000 cases when compared with conventional operations, provided that the following recommendations are adopted: (1) Select orders and replenish selection slots in the same aisle; (2) increase order size or use batch selection; and (3) program selection to take advantage of the multilevel selection machine's faster horizontal speed. The results also showed that multilevel operations using narrow-aisle equipment for rear replenishment would reduce warehouse costs by as much as $9.09 per 1,000 cases when compared with costs for conventional operations.

The largest savings were in facility occupancy costs. Occupancy costs per 1,000 cases shipped amounted to $31.68 for the conventional operations, $18 for the multilevel, rear-replenishment operation, and $12 for the multilevel, common-selection replenishment operation.

The major conclusion of this analysis is that management should consider all the opportunities for a multilevel operation, rather than considering a multilevel operation as just another device to increase order selector productivity. The study shows not only that the adoption of a multilevel operation by itself will reduce overall warehouse costs, but also that one should consider the entire concept behind a multilevel operation.

To attain the maximum benefit from a multilevel operation for low-volume grocery items, the operation should be well planned and involve more than the selector machine. Some examples of what to include in the plan are: (1) Selection and replenishment should be performed in the same aisles; (2) efficient selector flow patterns must be developed and the computer programed to print order-picking lists that route order selectors over the most efficient pattern; and (3) order size must be increased either by batch picking or by reducing the frequency that retail stores can order low-volume items.

INTRODUCTION

A maxim in the food-warehousing industry is: 20 percent of the items handled account for 80 percent of the products moved. Conversely, 80 percent of the items handled account for only 20 percent of the products moved. The 80 percent of the items that comprise the 20 percent of the products moved occupy considerably more than 20 percent of the valuable warehouse space in conventional warehousing operations. With the trend toward a greater number of grocery items in supermarkets, more warehouse space will be occupied by low-volume items unless new methods or systems for handling these items are developed.

The objective of this study was to compare three multilevel operations for low-volume grocery items with the conventional operation now being used, and to determine the conditions

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[1] Respectively, marketing specialist, Food Distribution Research Laboratory, Agricultural Marketing Research Institute, Northeastern Region, Agricultural Research Service, Beltsville, Md. 20705, and president, Paul F. Shaffer Co., Miami, Fla.

under which a multilevel operation may have lower costs than a conventional operation.

Data for the multilevel operations were obtained by conducting studies and interviewing managers in three food warehouses. Data for the conventional operations were obtained by conducting studies in two warehouses and from secondary sources. Studies were conducted in one warehouse before and after the installation of a multilevel operation.

MULTILEVEL OPERATIONS AND THEIR POTENTIAL IMPACTS

The purpose of this section is to acquaint the reader with multilevel operations and some of their potential impacts on overall grocery warehouse operations.

Multilevel operations, as the term implies, is the use of many pallet-rack levels for storing and selecting products to fill a customer's order.

In conventional warehouse operations, products are selected from two or three levels of pallet-rack storage, usually up to a height of approximately 8 feet above the floor of the warehouse.

Products are placed into reserve storage in the pallet rack above the selection area.

As shown in figure 1, the selection of items occurs at the lower two levels (three levels for items in smaller cases and very low-volume items), while the reserve storage area is above these two levels. In warehouses where multilevel operations are used, products may be selected from pallet-rack storage up to the maximum stacking height of the warehouse (usually to 4 feet below the ceiling) (fig. 2).

Much reserve storage is required for high-volume grocery items because of their rapid movement through the warehouse. Without a large reserve storage area, the rate of out-of-stock items would be very high, and eventually

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Figure 1.—Pallet racks used in conventional grocery warehouse operations.

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Figure 2.—Pallet racks and shelving used in a multilevel operations area.

customers would start seeking other suppliers. However, for low-volume grocery items, the amount of reserve storage should be less than for high-volume items because a large inventory is not necessary.

Equipment for selecting orders would differ between multilevel and conventional operations. In warehouses with conventional operations, order selectors generally use more than one type of equipment. The types of equipment used in conventional operations involve placing cases onto: (1) Selector carts that are either pushed manually or pulled mechanically, (2) pallets being hauled on selector carts that are either pushed manually or pulled mechanically, (3) pallets that are hauled mechanically with electric pallet jacks, and (4) mobile carts that are pulled mechanically. Mobile carts being pulled by a radio-controlled tugger are shown in figure 3.

In warehouses with multilevel order selection, machines elevate the order selector and the equipment (usually mobile carts) to the proper

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Figure 3.—Mobile carts being pulled by a radio-controlled tugger.

pallet-rack level. One example of the machines used for order selection in a multilevel operation is shown in figure 4. This machine is attached to a guide rail (see lower left side of the machine shown in fig. 4) to provide horizontal guidance. The selector controls the vertical and horizontal movement of the machine.

Multilevel operations must be conducted in a separate area from conventional operations, because both operations cannot occur in the same aisles. Separation of the two operations involves establishing a multilevel order selection area and moving the low-volume products to that area. Once the manager has determined the quantity of items to be placed in the multilevel order selection area, he can calculate the amount of space to be set aside.

In conventional operations, the aisles are generally 11½ to 12 feet wide. In multilevel operations, the aisles used for order selection are 6 feet wide (about 1 foot wider than the equipment used). The selection slots are usually restocked or replenished from the rear with either narrow-aisle forklift trucks, such as straddle trucks, or reach trucks. The counterbalanced forklift trucks require aisle widths of from 11½ to 12 feet, while the straddle trucks or reach trucks,[2] with 40- by 32-inch pallets, require an aisle width of 7 feet (considered a "narrow aisle"). By using multilevel operations, one should decrease the amount of warehouse space devoted to low-volume items relative to conventional operations if restocking and order selection occur in the same aisle.

The extent to which multilevel operations will reduce warehouse space for low-volume items depends on the method of restocking. When a separate aisle is restocked, this aisle will be 11½ feet wide if counterbalanced forklift trucks are used, and 7 feet wide if narrow-aisle forklift trucks are used. In two firms studied where multilevel operations were used for low-volume grocery (and health and beauty aid) items, narrow-aisle straddle trucks were used for restocking. In these firms, the total width of the six restocking aisles amounted to 46½ feet, compared with 69 feet if counterbalanced forklift trucks had been used for restocking.

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Figure 4.—Machine used for multilevel order selection.

Separating the low-volume items from the high-volume items should increase order selector productivity. Order selectors in the warehouse area where fast-moving items are stored would not have to travel past (and not select) a large number of selection slots that hold slow-moving items. Generally, the selector will walk past the low-volume items 5 to 10 times without selecting a case.

The apparent potential impacts of multilevel operations for slow-moving grocery items on total warehouse operations are summarized as follows: (1) Reduced warehouse space for slow-moving items; and (2) increased order selector productivity for all items. One of the not-so-readily-apparent impacts is better control through computers. The rest of this report measures the potential impacts and benefits from multilevel operations relative to conventional operations for low-volume items.

[2] A straddle forklift truck and wing pallets can be used with the multilevel selection system, provided that the guide rail for the selection machine is 5 inches or more above the floor.

COSTS OF EQUIPMENT, FACILITY, AND LABOR FOR MULTILEVEL OPERATIONS COMPARED WITH COSTS FOR CONVENTIONAL OPERATIONS

Differences in equipment, facility, and labor requirements between multilevel and conventional operations for low-volume grocery items have been discussed in general terms. The purpose of this section is to compare and discuss the costs associated with multilevel and conventional operations.

Equipment Costs

Pallet racks and order selection equipment were the two equipment categories where differences occurred between multilevel and conventional operations. Each of these equipment categories will be discussed separately.

Pallet Racks

To compare the costs for pallet racks used in the two operations, the following assumptions were made:

1. For the conventional operation, all low-volume items were placed on 40- by 32-inch pallets (no hand stacking), and the pallets were stored in pallet racks that had bays that were 111 inches wide and that were capable of holding three pallets. The pallet racks had uprights that were 192 inches high. One-half (50 percent) the items were selected from two rack levels, and one-half from three rack levels. The average pallet capacity (based on actual case count) amounted to 25 cases.[3]

2. For multilevel operations, all items were stored on 40- by 32-inch pallets in pallet racks that had bays that were 111 inches wide and capable of holding three pallets. The items were selected from seven rack levels. The average pallet capacity (based on actual case count) amounted to 30 cases.[4]

3. Inventory turnovers for both operations amounted to 10 per year.

Based on these assumptions and on costs reported by the cooperators in the study, pallet-rack costs amounted to $2.58 for conventional operations and $2.23 for multilevel operations per 1,000 cases shipped,[5] a difference of $0.35 per 1,000 cases in favor of the multilevel operations.

Selection Equipment

To compare the costs for order selection equipment, both types of operations (conventional and multilevel) were assumed to use mobile carts. Only the costs of power units were compared.

The power unit used in the conventional operations was an electrically powered tugger. The annual ownership and operating costs of the tugger amounted to $2.00 per 1,000 cases selected.[6] One tugger was assumed to be capable of handling the low-volume selection.

The power unit used in the multilevel operations was an electrically powered selector vehicle similar to the one shown in figure 4. The annual ownership and operating costs for the selector vehicle amounted to $5.85 per 1,000 cases selected,[6] or $3.85 more per 1,000 cases than the costs for the tugger used in conventional operations.

Facility Occupancy Costs

As discussed in "Multilevel Operations and Their Potential Impacts," multilevel operations must be performed in an area separated from the conventional operations, but not necessarily by a fixed partition (fig. 5).

To facilitate comparing the occupancy costs

[3] In conventional warehouse operations where selection is performed from three rack levels, less-than-full pallet loads must be placed in the three-level selection areas.

[4] Full pallet loads were placed in slots in the multilevel selection area.

[5] See appendix, part A, for the calculations used to determine pallet-rack costs.

[6] See appendix, part B, for the calculations used to determine annual ownership and operating costs.

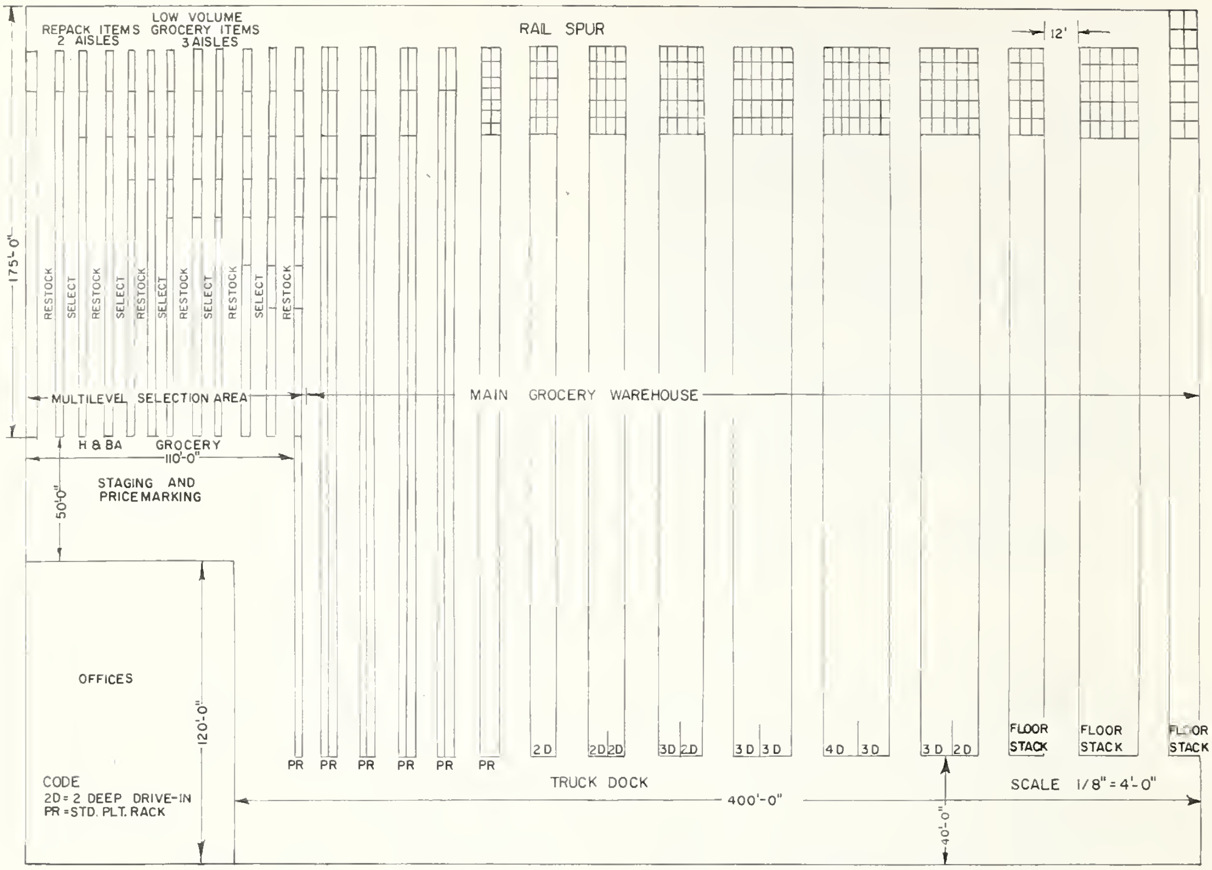

Figure 5.—Warehouse layout showing separate area for a multilevel operation.

for the two operations, the following assumptions were made:

1. Pallet-rack bays (space between uprights) were 111 inches wide.
2. Three pallet loads were stored on each pallet-rack level.
3. Seven pallet-rack levels of storage were used for the multilevel operation.
4. One-half (50 percent) of the low-volume items were stored on two pallet-rack levels, and one-half (50 percent) were stored on three pallet-rack levels for the conventional operation.
5. Two pallet-rack levels were used for reserve storage for the conventional operation.
6. Twenty percent of the pallet-rack slots were used for reserve storage for the multilevel operation.
7. Pallet loads amounted to 30 cases for the multilevel operation and 25 cases for the conventional operation.[7]
8. Occupancy costs were $1.25 per square foot for both.
9. Inventory turnover for both amounted to 10 per year.

Based on these assumptions, the occupancy costs per 1,000 cases selected amounted to $31.68 for the conventional operation and $18 for the multilevel operation[8] a difference of $13.68 per 1,000 cases in favor of the multilevel operation.

The lower occupancy costs resulted from less aisle space and more pallet-rack selection levels of products for the multilevel operation than for the conventional operation.

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[7] See footnote 3, p. 5.

[8] See appendix, part C, for the calculations used to determine facility occupancy costs.

Labor Costs

The two labor classifications studied for this cost comparison were: Labor used for selecting orders and labor used for restocking selection areas. Other warehouse labor would not be affected by the two operations.

Order Selection Labor Costs

Developing a true labor time-and-cost standard comparison for the two operations studied was difficult for two major reasons. First, each firm that used multilevel operations had different operating practices, such as fixed and floating (nonfixed) storage slots (location). With fixed storage slots, items were assigned to a specific slot. With floating storage slots, however, items were placed in the nearest available slot. Second, it was difficult to obtain a valid before-and-after comparison, because the installation of a multilevel operation is generally only one phase of a grocery warehouse reorganization or expansion, and because many factors influence order selector productivity. Some of the more important factors that affect order selector productivity are:

1. *Size of the order.* With large orders, more than one case will be selected for more items than with small orders. Studies in two test firms showed that on the average, order selector productivity for orders having more than 700 cases was 15 percent greater than for orders having less than 700 cases.

2. *Pick density of the order segment.* This is the number of cases selected, divided by the number of items. Usually, selectors are assigned parts of a store order rather than the entire store. This method reduces the time that a trailer will be parked at the dock and allows the selectors to become familiar with the entire warehouse. The pick density will vary by area in the warehouse. The part of selection most affected by density of pick is the "travel between picks" (fig. 6).[9] As the pick density increases, the travel time per case decreases.

3. *Warehouse layout.* Warehouse layout includes the placement of the selection racks (preferably perpendicular to the loading dock), the length of the selection rows, and the layout of the merchandise—high-volume and bulky items should be in the center of the warehouse and near the dock. Selection on one side of aisles and cross aisle picking for small orders will affect productivity.

4. *Type of rack and size of the pallet.* Selection of products is more difficult from bays that are 108 inches wide and that hold two 48- by 40-inch pallets using 40-inch facings than is selection from bays that are 111 inches wide and that contain two pallet sizes, 48 by 40 and 40 by 32 inches using 48-inch facings for the larger pallets. The 48-inch facing and 40-inch depth for the 48- by 40-inch pallet places more merchandise nearer the selector. The flexibility of two compatible pallet sizes in the 111-inch-wide bay allows the operator to adjust the storage pallet and type of rack to item movement. Three-level selection increases the time and the fatigue factors. Heavy cases in the bottom slots will reduce effort.

5. *Selector equipment.* Two basic selection platforms commonly used are the 48- by 40-inch pallet and the mobile cart. The choice of equipment depends on which platform has the lowest cost for the total selection—shelf-handling system.[10] Controlled tests revealed some advantage in selecting the pallet, but other considerations, such as the location of the stores and the possibility of backhauls, are of overriding importance. The speed of the tugger or electric jack is also important, especially with many small orders.

6. *Method of checking.* When the selector must hold the pick list in hand while selecting a case from the bay, the size of the list is a factor. Case labels will slow the order selection operation only when the label is attached after the case has been placed on the platform. The case label may, in fact, reduce the time for item checking since it eliminates pencil holding and

[9] The regression used to fit the curve shown in figure 6 was as follows: log Y = 0.0089 - 0.0017X; r = 0.76. The regression was based on a limited sample and used for illustrative purposes only.

[10] Costs of Handling Groceries From Warehouse to Retail Sales Floor With Warehouse Pallets and Mobile Carts. U.S. Dept. Agr., Agr. Res. Serv. ARS 52-69. April 1972.

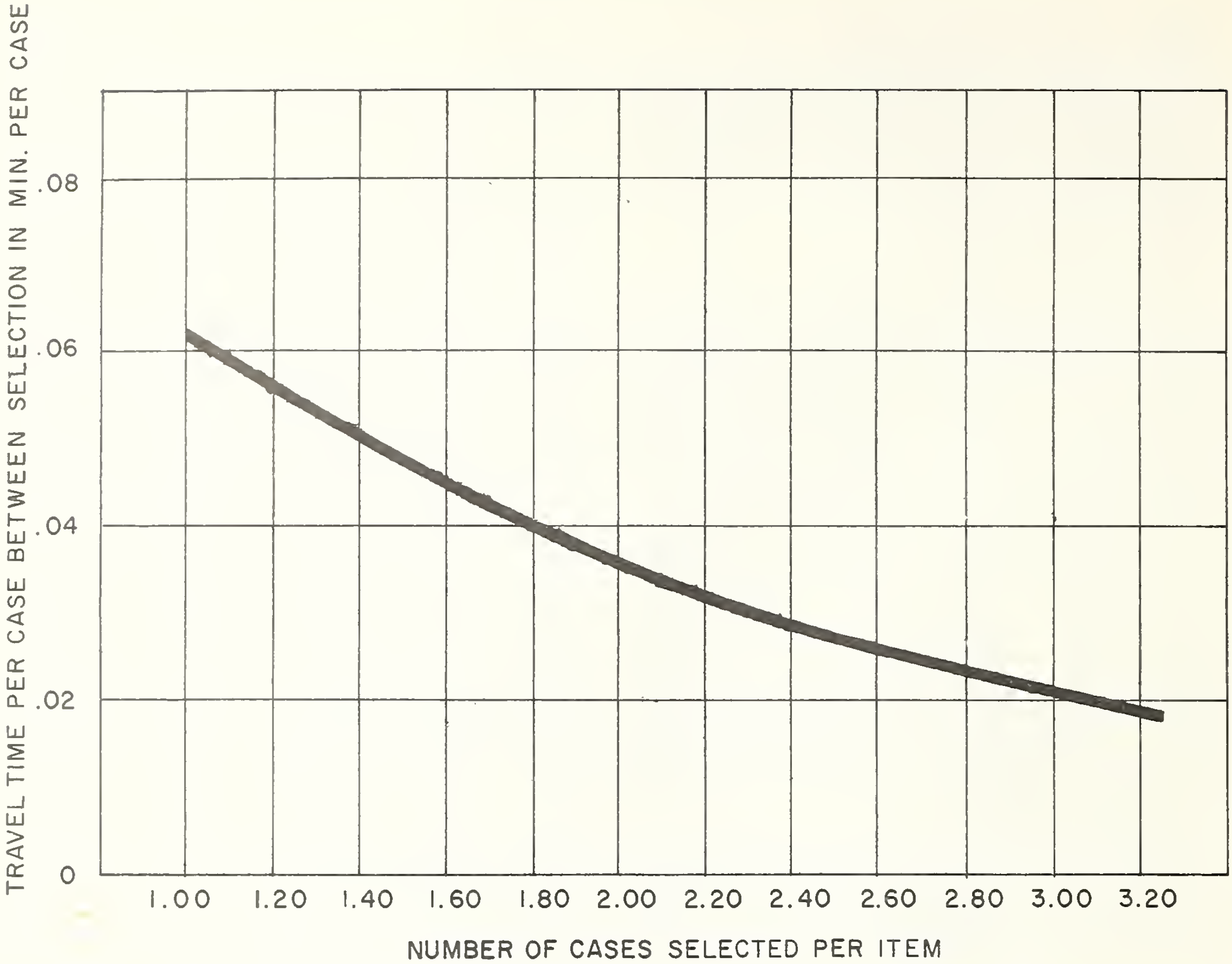

Figure 6.—Relationship of travel time between selections and number of cases selected per item in the main grocery warehouse of one firm studied.

the necessity to stop and check off the item every fourth or fifth case.

7. *Other factors that affect selector productivity.* Delays in the aisle, especially delays for a letdown by the fork operator, have an impact on productivity. In one firm, the delays represented 15 percent of total selection time. Combining the receiving with the selecting shifts will create congestion both in the aisles and on the dock. Finally, and probably the most important factor affecting selector productivity is the quality of management.

One of the multilevel operations studied was in a firm whose overall operation was also studied as part of an earlier U.S. Department of Agriculture research project.[11] At that time, the firm was using the conventional operation for all grocery items. Since then, the firm has incorporated a multilevel operation for low-volume grocery items. A more valid comparison will result from using data based on order selector productivity before and after the multilevel operation was adopted. If adequately established, time standards will not change for any job if methods and equipment remain the same.

Before a multilevel operation had been installed, the overall order selector productivity

[11] See reference listed in footnote 9.

was 218 cases per man-hour in the firm being studied. After a multilevel operation had been installed (8 percent of the cases shipped were transferred to the multilevel selection area), productivity for order selectors in the main warehouse increased to 236 (from 218) cases per man-hour or by approximately 8 percent. Order selector productivity in the multilevel area amounted to 175 cases per man-hour. The overall warehouse selection productivity increased to 231 cases per man-hour or by approximately 6 percent. Based on a labor cost of $4.20 per man-hour, the increased order selector productivity resulted in a savings of $1.09[12] per 1,000 cases ($19.28 before multilevel operations - $18.19 after multilevel operations). More importantly, the $1.09 savings per 1,000 cases applies to the entire warehouse selection operation. For example, if the firm shipped 6 million cases per year, total labor savings would amount to $6,540.

Labor Costs for Selection-Slot Replenishment

Replenishing selection slots was studied in two firms that used multilevel operations. In both firms, replenishment occurred each day after order selection had been completed. Also, separate aisles (nonselection aisles) were used for replenishing. In one firm, floating storage slots and pallets were used for all replenishing. In the other firm, fixed storage slots were used, and either hand-stacking repack units or pallets for full cases were used for replenishing.

In the firm where pallets and floating slots were used, replenishment productivity was 638 cases per man-hour. In the firm where either hand stacking or pallets and fixed slots were used, replenishment productivity was 201 cases per man-hour for hand stacking and 488 for pallets. By comparison, a conventional warehouse operation had a replenishment productivity of 341 and 938 cases per man-hour, respectively, for hand stacking and pallet replenishing.

Converting the productivity figures into labor costs for replenishing with full-pallet loads, based on an hourly wage rate of $4.35, resulted in annual labor costs for replenishing selection areas of $6.82 and $4.64 per 1,000 cases shipped, respectively, for multilevel and conventional operations. The difference amounted to $2.18 per 1,000 cases in favor of the conventional operation.

[12] See appendix, part D, for the calculations used to determine labor costs.

Total Equipment, Facility, and Labor Costs

Total equipment, facility, and labor costs per 1,000 cases shipped for multilevel and conventional operations are shown in table 1.

Based on the results of this study, multilevel operations for low-volume grocery items, performed under the conditions described, cost $9.09 per 1,000 cases less than the conventional operations. The occupancy cost for the multilevel operation was the major factor that enabled it to cost less than the conventional operation.

TABLE 1.—*Total equipment, facility, and labor costs per 1,000 cases shipped for multilevel operations compared with conventional operations for low-volume grocery items in food warehouses*

Cost item	Multilevel operations	Conventional operations	Savings with multilevel operations
	Dollars	*Dollars*	*Dollars*
Equipment:			
Pallet racks	2.23	2.58	+0.35
Selection	5.85	2.00	-3.85
Total	8.08	4.58	-3.50
Facility:			
Occupancy	18.00	31.68	+13.68
Labor:			
Selection	18.19	19.28	+1.09
Replenishment . .	6.82	4.64	-2.18
Total	25.01	23.92	-1.09
Grand total . . .	51.09	60.18	+9.09

RECOMMENDATIONS FOR FUTURE MULTILEVEL OPERATIONS

While the multilevel operations were being studied, three potential areas for improvement were observed. First, selection-slot replenishment should be changed to selection and replenishment from the same aisle. Second, since the machine used for order selecting in the multilevel operation had faster horizontal speed than vertical speed, the order selection pattern should be designed to maximize the use of horizontal travel. Finally, the order size should be increased or batch selection (the selection of more than one order at a time) used to increase order selector productivity by increasing order density.

Changing Selection-Slot Replenishment

Replenishing selection slots from the selection aisle would reduce the area required per pallet-rack bay in the multilevel area from 111 square feet to 60.12 square feet (46 percent).[13] By this method, occupancy costs per 1,000 cases would be $12. This amount is $6, $10, and $19.68 less than the costs of multilevel operations with narrow-aisle lift trucks (either straddle or reach trucks), multilevel operations with replenishment and selection in separate aisles, and conventional operations, respectively (table 2). Replenishing from the selection aisle was assumed not to change replenishment costs.

[13] See appendix, part C.

Changing the Selection Pattern

In the firms studied for multilevel operations, the selection pattern required the selectors to average approximately 75 percent of their travel time in moving vertically and 25 percent in moving horizontally. Since the machine had a faster horizontal speed than vertical speed, more horizontal travel than vertical travel woud be required.

For example, in one firm the order selector made one round trip in each aisle. On his trip down the aisle, the order selector selected from levels 1 through 4, and on his return trip, he selected from levels 5 through 7. For one 92-case order, the order selector moved vertically 64 times and horizontally 25 times, for a total of 89 movements. The 89 movements took 9.78 minutes of travel time.

To reduce the amount of vertical travel in proportion to the amount of horizontal travel, various combinations of travel directions were simulated. The best combination was three trips

TABLE 2.—*Warehouse occupancy costs per 1,000 cases resulting from replenishing multilevel slots using narrow aisles and common selection-replenishment aisles compared with using wide aisles for both multilevel and conventional order selection*

Replenishment method	Occupancy costs per 1,000 cases	Savings resulting from using narrow aisles for replenishing	Savings resulting from using common selection-replenishment aisles
	Dollars	*Dollars*	*Dollars*
Multilevel			
Separate selection-replenishment aisle	22.00	+4.00	+10.00
Narrow aisles	18.00	---	+6.00
Common selection-replenishment aisle	12.00	-6.00	---
Conventional	31.68	+13.68	+19.68

in an aisle (although this arrangement involved deadheading on the return trip to the shipping dock), selecting from levels 1, 2, and 3 on the first trip, from levels 4 and 5 on the return trip, and from levels 6 and 7 on a second trip. The best combination, if adopted, would result in a potential reduction of 2.35 minutes (24 percent) of travel time (from 9.78 to 7.43 minutes) and in a potential increase in overall order selector productivity. The increased order selector productivity would result in a savings of $1.78 per 1,000 cases over the multilevel operation that required more travel.

Increasing Order Size

Order size may be increased by using one or a combination of the following methods: (1) Limiting the frequency that each retail customer may order low-volume items; and (2) batch selecting low-volume items. Each method will be discussed.

The volume of items in the multilevel area turn over less than other grocery items; therefore, the retail store could reduce its order frequency. Generally, the retail store will sell less than five units per low-volume item in a week. If the store has 2 display facings that are 2 units high and 4 units deep, 16 units can be displayed at any one time. Therefore, the store could easily order this unit every 2 weeks and possibly every 3 weeks rather than every week. If the retail store has a space-allocation program, it is generally required to provide display space for one case plus 1 week's sales. This store could easily defer ordering low-volume items for 1 or 2 weeks without being out of stock.

Limiting the frequency that each retail customer can order low-volume items will increase order size. As shown in figure 7, order selector productivity (cases selected per man-hour) increases as order size (number of cases per order) increases. The curves shown in figure 7 were estimated from data obtained by conducting time studies of the selection operation in three multilevel operations. The regressions used to fit the curves are as follows:[14]

1. For firm 1:
   $\text{Log } Y = 2 + 0.0028X; r = 0.91$
2. For firm 2:
   $\text{Log } Y = 2.05 + 0.0012X; r = 0.89$
3. For firm 3:
   $\text{Log } Y = 1.78 + 0.0026X; r = 0.82$
4. For the three firms combined:
   $\text{Log } Y = 2.07 + 0.0017X; r = 0.73$

Referring to the curve for firm 1 (the firm used for selector productivity in the previous section), if order size were to increase from 80 cases to 150 cases, then order selector productivity in the multilevel order selection area would increase from 175 cases per man-hour to approximately 260 cases per man-hour or by approximately 60 percent, and overall warehouse order selector productivity would increase from 231 to 238 cases per man-hour.

Converting the productivity increase into cost per 1,000 cases results in a decrease in cost from $18.19 (1,000 cases ÷ 231 cases per man-hour x $4.20 per man-hour) to $17.64 (1,000 cases ÷ 238 cases per man-hour x $4.20 per man-hour)

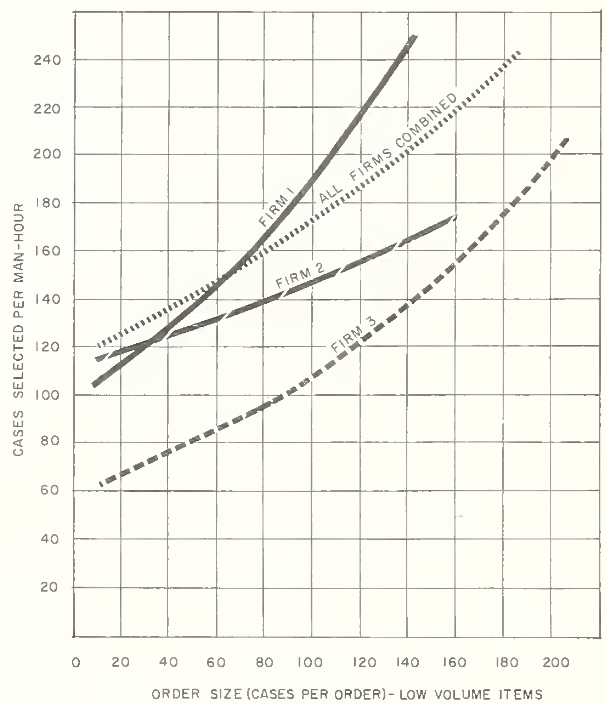

Figure 7.—Relationship between cases selected per man-hour and order size for multilevel order selection in three firms.

[14]The regressions were based on a limited sample in the firms studied and are used for illustrative purposes only.

or by $0.55 per 1,000 cases. Increasing order size would also increase productivity in conventional operations, especially if the wholesaler has a large number of small retail customers.

The second method recommended for increasing order density is to adopt batch selecting, particularly for small orders. Batch selecting is the term used to indicate selecting of more than one retail store order by an order selector during one trip through the warehouse. Batch selecting requires concentration by the order selector. However, time studies of the selection of two small orders reveal that approximately the same time is required as selecting one order equal in size to the two that were batch selected.

If mobile carts equipped with a shelf are used in the multilevel operation, then each level of the cart can be used for a separate store. The items for one store may have to be transferred to another cart, but the transferring operation requires only 10 minutes per 1,000 cases.

TABLE 3.—*Total equipment, facility, and labor costs per 1,000 cases shipped for the 2 improved multilevel operations compared with conventional operations for low-volume items in food warehouses*

Cost item	Multilevel operations using common replenishment selection aisle	Multilevel operations using narrow-aisle lift truck and rear replenishment	Conventional operations
	Dollars	*Dollars*	*Dollars*
Equipment:			
Pallet racks	2.23	2.23	2.58
Selection	5.85	5.85	2.00
Total	8.08	8.08	4.58
Facility:			
Occupancy	12.00	18.00	31.68
Labor:			
Selection	15.94	15.94	19.28
Replenishment ..	6.83	6.83	4.64
Total	22.77	22.77	23.92
Grand total ...	42.85	48.85	60.18

Cost Comparison for the Recommended and Actual Multilevel Operations and Conventional Operations

The equipment, facility, and labor costs resulting from these recommended changes and the costs resulting from the actual operations discussed in the previous section are shown in table 3. The least expensive method was the multilevel operation that used the same aisles for selection and replenishment. Costs for the least expensive method were $6 ($48.85 - $42.85) per 1,000 cases less than costs for the multilevel operation that used narrow-aisle straddle trucks and rear replenishment, and $17.33 ($60.18 - $42.85) less than costs for the conventional operation.

The greatest cost savings were due to the reduction of warehouse space, a result of selecting and replenishing in a common aisle rather than in separate aisles. The occupancy costs for the least expensive method amounted to $12 per 1,000 cases shipped and were $6 and $19.68 less, respectively, than the multilevel operation that used narrow-aisle straddle trucks with rear replenishment and the conventional operation.

CONCLUSIONS

This study was designed to analyze multilevel operations for low-volume grocery items and to make recommendations to increase productivity and reduce costs in future multilevel operations. The results of the analysis showed that multilevel operations will increase overall warehouse selector productivity, decrease the amount of warehouse space occupied, and reduce costs relative to conventional operations. More importantly, overall warehouse order selector productivity could be further increased, warehouse space reduced, and costs lowered with the

adoption of the following procedures: (1) Selection and replenishment should be performed in the same aisles; (2) efficient selector flow patterns must be developed and the computer programed to print order-picking lists that route order selectors over the most efficient patterns; and (3) order size must be increased either by batch picking or by reducing the frequency that retail stores can order low-volume items.

APPENDIX—CALCULATIONS USED TO ESTIMATE EQUIPMENT, FACILITY, AND LABOR COSTS

A. Pallet-Rack Costs
1. Conventional operations.
   a. \$72 cost per pallet-rack bay + \$18 estimated installation cost = \$90 initial cost per pallet-rack bay.
   b. \$90 initial cost per pallet-rack bay ÷ 15 years depreciation = \$6 annual depreciation costs per pallet-rack bay.
   c. \$90 initial cost per pallet-rack bay ÷ 2 x 0.06 interest = \$2.70 annual interest cost on investment per pallet-rack bay.
   d. \$6 annual depreciation cost per pallet-rack bay + \$2.70 annual interest cost per pallet-rack bay = \$8.70 annual pallet-rack cost per pallet-rack bay.
   e. \$8.70 annual pallet-rack cost per pallet-rack bay ÷ 3,375 cases shipped per bay per year (average of 13.5 pallets per bay[15] x 25 cases per pallet x 10 inventory turnovers per year) = \$2.58 annual pallet-rack costs per 1,000 cases shipped.
2. Multilevel operations.
   a. \$115 cost per pallet-rack bay + \$30 estimated installation costs = \$145 initial cost per pallet-rack bay.
   b. \$145 initial cost per pallet-rack bay ÷ 15 years depreciation = \$9.67 annual depreciation cost per pallet-rack bay.
   c. \$145 initial cost per pallet-rack bay ÷ 2 x 0.06 interest = \$4.35 annual interest cost on investment per pallet-rack bay.
   d. \$9.67 annual depreciation cost per pallet-rack bay + \$4.35 annual interest cost per pallet-rack bay = \$14.02 annual cost per pallet-rack bay.
   e. \$14.02 annual cost per pallet-rack bay ÷ 6, 300 cases shipped per bay per year (21 pallets per bay x 30 cases per pallet x 10 inventory turnovers per year) = \$2.23 annual pallet-rack costs per 1,000 cases shipped.

B. Order Selection Equipment Costs
1. Conventional operations.
   a. \$3,500 cost of the tugger + \$750 cost of the battery + \$450 cost of the battery charger = \$4,700 initial cost of tugger.
   b. \$4,700 initial cost of tugger ÷ 8 years depreciation = \$587.50 annual depreciation cost of tugger.
   c. \$4,700 initial cost of tugger x 0.05 annual maintenance = \$235 annual maintenance cost of tugger.
   d. \$4,700 initial cost of tugger ÷ 2 x 0.06 interest = \$141 annual interest cost of tugger.
   e. \$587.50 annual depression cost + \$235 annual maintenance cost + \$141 annual interest cost = \$963.50 total annual ownership

[15] Calculated as follows: (1) Two-level selection = 12 pallets (2 selection levels x 3 pallets per level + 2 levels of reserve storage x 3 pallets per level); (2) 3-level selection = 15 pallets (3 selection levels x 3 pallets per level + 2 levels of reserve storage x 3 pallets per level); (3) 12 pallets + 15 pallets = 27 pallets ÷ 2 = 13.5-pallets-per-bay average.

costs of tugger ÷ 480,000 cases shipped per year per tugger = $2.00 annual tugger cost per 1,000 cases shipped.

2. Multilevel operations.
   a. $12,500 cost of the selector vehicle + $750 cost of the battery + $450 cost of the battery charger = $13,700 initial cost of selector vehicle.
   b. $13,700 initial cost of selector vehicle ÷ 8 years depreciation = $1,712.50 annual depreciation cost of selector vehicle.
   c. $13,700 initial cost of selector vehicle x 0.05 annual maintenance = $685 annual maintenance cost of selector vehicle.
   d. $13,700 initial cost of selector vehicle ÷ 2 x 0.06 interest = $411 annual interest cost of selector vehicle.
   e. $1,712.50 annual depreciation cost + $685 annual maintenance cost + $411 annual interest cost = $2,808.50 total annual ownership costs of selector vehicle ÷ 480,000 cases selected per year = $5.85 annual selector vehicle cost per 1,000 cases shipped.

C. Facility Occupancy Costs
1. Conventional operations.
   a. 9.25 feet (5.75 feet for the aisle + 3.50 feet for pallet-rack depth) x 9.25 feet rack width = 85.56 square feet per pallet-rack bay.
   b. 85.56 square feet per pallet-rack bay ÷ 13.5 average number of pallets per pallet-rack bay = 6.34 square feet per pallet.
   c. 6.34 square feet per pallet x $1.25 occupancy cost per square foot = $7.93 annual occupancy cost per pallet space.
   d. $7.93 annual occupancy cost per pallet space ÷ 250 cases per pallet space (25 cases per pallet x 10 inventory turnovers per year) = $0.0368 annual occupancy cost per case shipped.
   e. $0.0368 annual occupancy cost per case shipped x 1,000 cases = $31.68 annual occupancy cost per 1,000 cases shipped.
2. Multilevel operations (selection and replenishment performed in separate aisles).
   a. 12 feet (3 feet for a selection aisle + 3.5 feet for pallet-rack depth + 5.5 feet for replenishment aisle) x 9.25 feet rack width = 111 square feet per pallet-rack bay.
   b. 111 square feet per pallet-rack bay ÷ 21 pallets per pallet-rack bay = 5.28 square feet per pallet.
   c. 5.28 square feet per pallet x $1.25 annual occupancy cost per square foot = $6.60 annual occupancy cost per pallet space.
   d. $6.60 annual occupancy cost per pallet space ÷ 300 cases shipped per pallet space (30 cases per pallet x 10 inventory turnovers per year) = $0.022 annual occupancy cost per case shipped.
   e. $0.022 annual occupancy cost per case shipped x 1,000 = $22 annual occupancy cost per 1,000 cases shipped.
3. Multilevel operations (selection and replenishment performed in the same aisle).
   a. 6.5 feet (3 feet for aisle + 3.5 feet for pallet-rack depth) x 9.25 feet rack width = 60.12 square feet per pallet-rack bay.
   b. 60.12 square feet per pallet-rack bay ÷ 21 pallets per pallet-rack bay = 2.86 square feet per pallet.
   c. 2.86 square feet per pallet x $1.25 annual occupancy cost per square foot = $3.58 annual occupancy cost per pallet space.
   d. $3.58 annual occupancy cost per pallet space ÷ 300 cases shipped per pallet space (30 cases per pallet x 10 inventory turnovers per year) = $0.012 annual occupancy cost per case shipped.

e. $0.012 annual occupancy cost per case shipped x 1,000 cases = $12 annual occupancy cost per 1,000 cases shipped.

4. Multilevel operation (replenishment from rear using narrow-table straddle trucks).
   a. 9.8 feet (6.3 feet for aisles + 3.5 feet for pallet-rack depth) x 9.25 feet rack width = 90.65 square feet per pallet-rack bay.
   b. 90.65 square feet per pallet-rack bay ÷ 21 pallets per bay = 4.32 square feet per pallet.
   c. 4.32 square feet per pallet x $1.25 annual occupancy cost per square foot = $5.40 annual occupancy cost per pallet space.
   d. $5.40 annual occupancy cost per pallet space ÷ 300 cases shipped per pallet space (30 cases per pallet x 10 inventory turnovers per year) = $0.018 annual occupancy cost per case shipped.
   e. $0.018 annual occupancy cost per case shipped x 1,000 cases = $18 annual occupancy cost per 1,000 cases shipped.

D. Labor Costs for Order Selection
1. Conventional operations.
   a. 1,000 cases shipped ÷ 218 cases selected overall per man-hour = 4.59 man-hours per 1,000 cases shipped.
   b. 4.59 man-hours per 1,000 cases shipped x $4.20 per man-hour = $19.28 labor cost for selecting 1,000 cases.

2. Multilevel operations.
   a. 1,000 cases shipped ÷ 231 cases selected overall per man-hour = 4.33 man-hours per 1,000 cases shipped.
   b. 4.33 man-hours per 1,000 cases shipped x $4.20 per man-hours = $18.19 labor cost for selecting 1,000 cases.

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